Theoretical Framework Of Housing Health Performance Evaluation

E. Hasselaar

OTB Research Institute for Housing, Urban and Mobility Studies, Delft University of Technology, P.O. Box 5030, 2600 GA Delft, The Netherlands
email: e.hasselaar@tudelft.nl

Summary: Performance evaluation receives much attention from indoor specialists and from occupants. The paper presents a theoretical framework for the strategy of designs for instrumentation for health performance evaluation. Performance evaluation requires the selection of a set of simple and robust indicators. The health topics that are covered by these indicators are indoor air, risk of injury, functional and thermal comfort, acoustics, safety and social quality. Problem solving is placed in the context of performance management of housing. Communication between the housing manager and the occupant, while dealing with complaints and identifying who is responsible actions, is essential in the framework.

Keywords: healthy housing; performance evaluation, tools
Category: Risk assessment in relation to indoor exposures

1 Introduction

The relation between housing and health is not well understood by occupants and housing managers and opportunities to reduce hazards and to adapt houses to the health needs of households are missed. Health criteria were until recently poorly integrated in sustainable building, and technical innovations that contribute to energy savings are sometimes in conflict with good health performance of housing. Poor communication about complaints or about who is responsible for dealing with health hazards is a threshold for a good diagnosis of problems and for taking action on remediation.

Health performance evaluation of housing identifies hazard conditions. However, performance evaluation is not widely adapted, because of cost, because it is not legally required (except in the United Kingdom) and because housing managers miss the knowledge to do this type of environmental assessment. Despite this context, four new tools have been introduced in The Netherlands since early 2003. The focus of these tools, their potential use and impact on healthy housing was analysed, to use experience as a stepping stone for the next tool.

The question is: how to design health performance instrumentation that has optimal positive impact on healthy housing? A theoretical framework for performance evaluation is constructed, so the strategy and design for a new tool can be based on clear requirements. This framework deals with the physical properties of houses including functions and technical services, the occupancy and occupant behaviour and the hazards that occupants are exposed to. The occupant is the main subject. Occupant health is influenced by physical and mental conditions, by perception and behaviour and by being involved and in control of the environment [1].

Context and definitions
The preoccupation is with the housing stock, which means that conditions can be observed and measured in a single occupied dwelling. We do not deal with the health effects of construction and maintenance workers, not with the future effect of demolition etc. A hazard is something with the potential to cause harm. Risk is the possibility, with a certain degree of likelihood, of a hazard causing harm. An indicator of health performance is a marker, selected from a variety of building and occupancy characteristics, that has the power to represent the health potential of a condition. Indicators do not prove the health effect, but make a connection between the environment and personal health risk. Health performance evaluation is the evaluation of these indicators. It requires a visit of a dwelling with the goal of identifying exposure risks, so these risks can be avoided or taken away. Performance evaluation requires careful selection of simple and robust indicators. The health topics that are covered by these indicators are indoor air, risk of injury, functional and thermal comfort, acoustics, security and social support. The home inspector uses a protocol for data collection, analysis and diagnosis, communicates with the occupant and reports the results. The occupant can do an inspection as well. Occupancy includes the size and type of the household, the user patterns of each room and the health needs of the occupants. Occupant behaviour refers to the type of control over the environment, or of adaptation of user patterns to the given conditions of the physical environment. The health impact depends on occupant exposure to indoor air pollution and to physical conditions that cause hazards. The exposure to air pollutants depends on the concentration, which is the result of source strength and ventilation. The exposure to physical and mental hazards depends on the conditions that cause health effect, including the perception of harm.
2 Method

Theory and practice

The theoretical analysis is combined with a descriptive context. A theoretical framework is constructed that connects the house, the occupants and health, or in more detail: that connects housing management, occupant needs and behaviour to conditions in support of health. The theoretical context is derived from systems theory, communications theory, and environmental risk assessment. An integrated model of housing health performance is presented. The descriptive context comes from the analysis of practical tools. The evaluation criteria are derived from the framework. These criteria are described while the evaluation itself will be available in a book [12].

Elements of the integrated framework

Environmental health science starts at either end: from health effects in human beings to the diagnosis of environmental conditions that cause these effects (bottom-up), or from hazard conditions to potential health effect (top-down). The second approach provides the driving force-pressure-state-exposure-effect (DPSEEA) framework [4]. The house can be viewed as a system, the rooms as sub-systems. The occupant can be viewed as a system, dealing with environmental influences: the connection between two systems (house and occupant). This viewpoint leads to systems theory and the framework of systems control (input, throughput, output and outcome) placed in an external environment [5].

The need to select indicators

Health is usually viewed from a scientific perspective, making it possible to diagnose hazards, for instance microbes or chemicals, and to relate these to physiological changes in humans. In houses, the concentrations of pollutants are often quite low and it is hard to establish dose-response relations. These relations are often derived from extreme occupational environments. Modelling of these extremes results in permissible concentrations in houses. Exceeding these concentrations supposedly increases health risk, without proof on the basis of an individual house. This experience leads to the necessity to use markers that substitute dose-effect relations by “indication” of exposure to hazard conditions. These indicators point at health risk. The use of indicators instead of dose-response studies in the individual house means that health performance evaluation represents an indirect and qualitative method. Indicators are the key items of tools. The selection of indicators is an essential element in the design process of instrumentation for health performance evaluation. The theoretical framework could support the selection process.

Indicators that are clearly defined ensure consistent inspection protocols and similar results from different inspectors. Many indicators of the relation housing, occupancy and health relate to complex conditions, including "if"- or "and"-conditions (fuzzy logic). Models of complex conditions that are evaluated on the basis of a combination of indicators provide insight in the marker function of the respective individual indicators: modelling results in "proxy" indicators. Indicators can be selected on the basis of validity and reliability in combination with user friendliness in its application (alignment). The search is for robust indicators. Robust means: focused, aligned, easy to use, easy to evaluate, resulting in priority setting of health hazards. Robustness applies to the indicators and to the evaluation protocol as well. The study focuses on re-search (repeated search, as many indicators are available) for robust indicators.

The need to involve the occupant

Health effects can also be caused by perceived conditions, e.g. a state of satisfaction or emotions. When a person feels healthy, this person is healthy from an individual point of view. Perception is influenced by phenomena that the occupant is aware of, because of cognition or because of visible or thermal sensation or smell. Mean population perception of air pollution is found to correlate well with physical measures of actual air pollution, at least for those forms of pollution that humans can smell or feel. For this reason we include perception in the context of health performance. Perception is related to behaviour. Behaviour is a complex of actions that come from internal needs and external stimuli. Behaviour can be oriented towards control or self-efficacy. Lack of control or non-coping can result in stress. Allowing people greater control over the indoor environment have resulted in significant positive impacts on comfort [3]. Psychologists have clearly demonstrated that adverse or noxious stimuli are less irritating if the subject perceives to have control over them. Under stress, bodily defences against environmental hazards (e.g. infectious agents, irritating chemicals, glare, noise) are diminished. While perception itself influences the health condition, it means that measures that influence perception (for instance by improving comfort or providing control features) can have a positive impact on stress reduction and on health. Control by occupants of the individual environment is for that reason included in the context of health performance. Occupants may perceive problems or have manifest complaints, but fail to take action to solve problems. Lack of knowledge about how to diagnose the conditions or how to stimulate the home owner to acknowledge a complaint and to take action is an important threshold for improvement of the home environment. Also, complaints can be caused by conditions that are the effect of user patterns or behaviour that could be changed and better adapted to the requirements of healthy housing. Change of behaviour is more likely to be achieved when change results in more comfort, reaching needs or perception of improvement. In the field of rented housing, change is positively stimulated when physical improvement (by the home owner) is combined with...
involvement, information exchange and required adaptation to new conditions. For this reason we include occupant involvement in the context of health performance.

The role of communication

Recognition of occupant complaints by housing managers may be problematic, because the diagnosis is difficult and because of conflicting interest between the owner, who has to invest, and the occupant, who could avoid the condition leading to the complaint. Home owners tend to overrate the influence of occupants: e.g. complaints about moisture or mould and noise are blamed on poor behaviour, even when poor technical conditions have an important effect. Complaint handling starts with a careful diagnosis of problems, for which user friendly methods are needed that involve both housing managers and occupants. The need of sophisticated instruments or expert knowledge is in conflict with a user friendly protocol. Communication between housing managers and tenants will support a critical review of the process, stimulates the use of results and action taking. Also, communication itself results in better perception of control, in active information seeking, in self-efficacy, which influence health perception and therefore the communication process is an effective measure to improve healthy housing. For the owner occupant a do-it-yourself evaluation protocol will stimulate a learning process, resulting in more action taking and a critical look on individual behaviour. The topic of communication is positioned in the centre of the framework, connecting behaviour (complaints) with problem identification and problem solving.

3 Results

The exploration into theoretical concepts that apply to healthy housing, indicator selection and health performance evaluation results in a model in which three frameworks are integrated: the first is the DPSEEA framework of health risk assessment, the second deals with systems control and the third with communication theory.

The DPSEEA framework

The Driving force-Pressure-State-Exposure-Effect-Action framework developed over many years in the field of health risk assessment. The starting point was a simple pressure-state-response sequence applied by OECD (Organisation for Economic Cooperation and Development in Developed countries) as a framework for state-of-the-environment reporting. It has been extended to include both the 'driving forces' and of the effects. The result is Driving force-Pressure-State-Exposure-Effect-Action: the DPSEEA-framework for the development of environmental health indicators. This framework is applied in the home environment. The driving force component (D) represent the sources of agents and risk conditions, often related to occupancy load of the house. The driving force generates pressures (P) on the environment: pollution and hazards. In response to these pressures, the state of the environment (S) changes: there is a resulting concentration of pollutants or a certain hazard level. Environmental hazards, however, only pose risks to human well-being when humans are exposed (Exposure). It requires that people are present both at the place and at the time that the hazard occurs. Exposure to pollution is by inhalation, ingestion or by physical contact. In the home environment the exposure differs per room. Exposure to hazards leads to a wide range of health effects (E). The least intense effects are sub-clinical, merely involving some reduction in function or some loss of well-being. More intense effects may take the form of illness or morbidity.

Figure 1. The DPSEEA framework

With known exposures and knowledge of dose-response it is possible to make reasonable estimates of the potential health burden of specific pollutants. Indicators provide more rapid estimates of the health impact of specific environmental exposures. In the face of these effects, a range of actions (A) can be taken (adapted from [6]). The home inspector deals in the occupied house with “dose” mainly. Dose is the result of the sequence Driving force-Pressure-State-Exposure or DPSE. Many houses have similar features of Driving forces, so D can be assessed on the basis of a simple checklist of pollution sources and how they can be identified. Pressure consists of two phenomena: the emission and the removal of emitted material by ventilation or cleaning. For assessment of Pressure two types of indicators are selected: indicators of emissions and indicators of transport. Pressure can be assessed by inspection and interview. State can be hard to assess, for instance indoor air pollutants that are not visible, while smell is only a rough marker of the concentration. Concentrations of agents have to be measured, but if we cannot or do not want to measure because of the time, money or expertise involved, we have to use indicators that indirectly represent the concentration. Exposure differs per person and in time, but exposure periods differ mainly for the living room and kitchen, as the time spent in bedrooms and the bathroom is quite similar for every human being. By taking
standardised exposure periods of vulnerable persons (anybody sensitive or sick or with one or more disabilities) it is possible to choose a default exposure level. In other words: the health performance protocol can consist of the following main elements: checklist for D, inspection and interview in the house for P, indirect assessment of S on the basis of proxy indicators and finally default exposure for E. This sequence provides data for risk exploration. It means that inspection deals with P mainly: emissions (P+) and ventilation/cleaning (P-) are inspected on the spot.

The ITOO framework
The ITOO framework represents the Input-Throughput-Output-Outcome sequence and is developed in the field of performance measurement, which started in management theory, in the first place the economical management of companies and more recently the management of service-providing institutions such as banks, government bodies and also housing associations. An organisation is managed on the basis of input (money, people) and output (products) that are defined by actions and milestones, while the final outcome (are goals of the organisation realised?) receives more and more attention. The ITOO framework supports planning and control of performance. The line model of performance based management is translated to fit housing and health performance evaluation. See figure 2.

![Figure 2. Model of performance based management](image)

The ITOO-framework starts with input, that includes means, for instance human capital to do home inspections. We take the goal of a healthy house as example. Throughput is a sequence of activities and milestones to improve housing. These activities have effect on health performance: the output. Performance evaluation is to check if output is in line with the desired outcome, which is a healthy house. The DPSEE framework (Without A) focuses on problem identification, the ITOO framework on problem solving. The activity of problem identification requires a protocol for data collection and data analysis, including evaluation criteria to support risk ranking. For a user friendly quality of the protocol it is important that housing managers can 1) easily understand and use the protocol, 2) can value indicators on the basis of general information, 3) can recognise emissions and hazard conditions on the basis of visual inspection and 4) know how to aggregate exposure to potential hazard into a score. Even when data collection results in quantitative data, the result of evaluation is qualitative, which means that performance evaluation is a qualitative process. In such a process communication is important.

The communication framework
Communication between the inspector, the housing manager and the occupants connects data collection with evaluation results and decision taking on actions. Communication theory identifies a message, a sender, receiver and desired feedback. See Figure 3.

![Figure 3. The model of communication](image)

In the study the sender is the tenant with a complaint, who needs interaction with the housing association to discuss the problem and to agree on diagnosis and actions. The home owner can be the messenger as well, for instance to promote occupant behaviour that prevents problems. The desired feedback is change of perception which may result in change of behaviour. Filing a complaint is action taking after being aware of a problem. When the problem is not easy to solve, community action may be initiated: information seeking, interaction with neighbours, strategy formulation, taking initiative to improve control over the conditions that will result in problem solving. The communication process is a basic element of healthy housing. Reviews of renovation processes show that the feeling of occupants of being involved in the renovation process has a positive health effect [2]. Kleinhans (2005) states that personal guidance in relocating people after demolition of houses reduces the stress and dissatisfaction caused by the forceful change of environment [7]. The use of the Ventilation Checklist [8] by tenants shows that the evaluation by tenants of ventilation services, which is considered a complex topic, leads to better understanding, more action and even change of ventilation behaviour. Self learning works for those tenants that are motivated to fill out the Ventilation Checklist. Communication is an element of the problem solving process and also a process in itself: communication is essential in sense making [9]. Lawton [10] proposes the “environmental pro-activity hypothesis”. Pro-activity is the person’s competence to determine the environment. When the person becomes more competent, the environment affords more resources to meet the person’s needs. Personal resources are regarded as means by which one can engage in proactive behaviour, whereas reactive behaviour is simply a response to environmental press [10]. We transform pro-activity.
into competence to adapt the environment to needs, and to play an active role in control of quality. A "learning-by-doing" tool can stimulate active control through deliberate adaptation, instead of being victimised by the environment.

The model of health performance evaluation
An overall model is constructed by confronting housing and health and occupancy. The subject (occupants), the building (housing), health risk (health) are the three dimensions of this model. Behaviour in the model is the interaction with the environment. Health performance evaluation is the link between health and housing management. This results in a pyramid with three interrelated dimensions (housing, occupants and health) and four fields of attention (problem identification, problem solving, occupant behaviour and communication).

The main model presents 12 lines that either refer to conditions or processes. The framework includes three steps from perception of a problem to initiative for Action and one step for problem solving. The identification of hazards and interaction to reach agreements on the diagnoses and on actions are crucial for improving healthy housing. This exploration makes it possible to simplify the framework for the performance evaluation protocol to the model presented in figure 2 in which the main elements can be identified as: a checklist of Sources, a protocol for inspection and interview of Pressure plus State (emissions and transport) and a simple scenario that reveals the type of Exposure. The interview results in occupant's reports of needs, experiences and perceptions. The inspection results in “risk exploration” with qualitative risk ranking. Risk ranking will be the task of the inspector, who will have to understand dose-effect relations. Ranking on the basis of qualitative criteria is “intuitive” ranking, as opposed to ranking by comparison with standards (“objective” ranking) for which monitoring is required. After this problem identification process the next step is problem solving, and communication processes will facilitate decision making on actions. Actions to improve the health performance represent a new step in the process, and will often involve other persons and departments. Communication procedures (again) are essential in guiding this reorganisation.

Simplification
In order to make the evaluation protocol accessible to housing managers and occupants, the protocol needs a great deal of simplification. Simplification is possible by selecting proxy indicators, for instance: the number of persons present in one room is indicator of the concentration of bio-effluents. The occupancy load is a proxy indicator. Further simplification is possible by focusing the evaluation protocol on source, emission and transport indicators mainly. Risk ranking in this manner leads to ranking of exposure to a potential hazard or pollutant concentration. Ranking is relative ranking, based on a comparison of risk, resulting in values considered indicative for the likelihood and severity of hazardous situations. Likelihood is the probability of an occurrence of harm during a certain period following the assessment. Additional criteria may be considered: the magnitude of the population at risk; the possibility to control or avoid the hazard; the perception by stakeholders [11].

Aggregation of results
Aggregation of evaluation results for a dwelling into single scores would facilitate communication about the quality of dwellings. We can think of a label that can support better matching of housing needs and the selection of a house at turnover. As it is hard to compare the performance for air with water or safety, separate scores are used and aggregation will be limited to separate themes or policy fields. Aggregation is suggested for the “empty house” and “occupancy” and for the separate fields of air quality, acoustics, comfort, safety and social quality, maybe also for domestic water quality, privacy and relation with outdoor space (view, light) etc. How to find a balance between a preferred single score and a set of scores needs more exploration.
Requirements for performance evaluation tools
This exploration into theory results in a strategy for the design of health performance evaluation tools. The strategy has been applied in the Checklist Healthy and Safe Housing, presented in September 2005 (version for consumers on www.toetslijstgezondwonen.nl) and in April 2006 (professional version).

The first requirement is that the tool supports the interest of users. It means that the set of indicators is the basis for different versions of tools, for consumers, housing managers and project developers, for advisers and architects. It is essential that a tool is user friendly and in line with other tools used by the target group. The tool deals both with technical features and occupant behaviour. A visit with inspection and interview for a single dwelling is required. Special monitoring equipment and expert knowledge is not needed. A version for use in the design stage of projects is welcome. Testing pilot versions is required to find out if the input (time and cost) balances the output. Occupants can use the tool and are supported in critical evaluation of qualities and in taking action. The tool supports the selection and execution of relevant measures, both technical and in adaptive behaviour. The home visit is guided by an inspection protocol, information from an interview with the occupants, evaluation, reporting and presenting results. The house is inspected per room. A simple checklist is used, to see which items were overlooked during the inspection protocol, as a look-up guide for documentation and to support drawing of conclusions. The protocol supports integrative evaluation instead of focus on singular indicators. The quality scores follow five quality themes, representing one-item conditions: air quality, acoustics, thermal comfort, safety, quality of the social environment. Each of these five qualities are evaluated for the “empty” house and occupancy. Tips and measures are described and they support insight in the gap between the optimal quality and the present conditions. The final results include: answers to the items of the checklist for the empty house and occupancy; a list of major conflicts with good quality, the list of tips and measures and the ten scores.

5 Conclusion

New tools for health performance evaluation have become available. These tools are not widely used in the field of housing. A theoretical model of the relation occupants, housing, communication and health is constructed, based on the DPSEEA framework, systems theory and communication theory. The model results in criteria, used in the evaluation of existing tools. The results are translated into criteria for tool design. The main result of this paper is a theoretical model, that connects the sequential steps in the identification of environmental hazards (Driving force, Pressure, State, Exposure, Effect) with the management system of problem solving (Input, Throughput, Output, Outcome). The occupant is both subject and actor in learning and control or adaptation. Communication is an indispensable process element that changes performance evaluation from a technocratic expert domain into the domain of interaction between housing managers and tenants. This focus results in an action oriented tool. Risk ranking and aggregation of results in a single or limited number of scores needs further exploration.

References
[9] Dervin, B. (2001) What we know about information seeking and use and how research discourse community makes a difference in our knowing, Background paper prepared for Health Information Programs Development, National Library of Medicine, Bethesda, MD.